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Material Properties Affecting Solids Blending and Blender Selection: Bulk Density

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1 comment

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The bulk density of powders is one of the most important properties to be considered while designing blender. The quantity of material that can be blended per batch and the power required for blending depends largely on the bulk density of ingredients. This is explained using sample calculations.

Introduction

The preceding articles detailed the effects of flowability, particle shape, particle size, and distribution on blending and blender selection. The particle size distribution of powders and particle shape has an effect on the packing characteristics, and therefore the bulk density of solid powders. In this article we shall discuss the significance of the bulk density of solids in the design of blenders. The concepts of loose bulk density, packed bulk density, fluidized bulk density, and particle density are explained. The article provides basic guidelines for estimating the volumetric capacity of the blender and the power consumption, based on the bulk density of material.

Properties Affecting Blending

The material properties affecting blending are as follows:

- Angle of Repose
- Flowability
- Bulk Density
- Particle Size, Distribution
- Particle Shape
- Cohesiveness
- Adhesiveness
- Agglomeration
- Friability
- Corrosiveness
- Abrasiveness
- Explosiveness

- Material Composition
- Surface Characteristics
- Moisture or liquid content of solids
- Density, Viscosity, Surface tension of liquid added
- Temperature Limitations of Ingredients

Bulk Density - Definitions

Bulk density includes not only particle mass but also the air entrained in the void spaces between the particles. There are three types of bulk density – loose bulk density, packed bulk density, fluidized bulk density. CEMA defines the bulk density as follows [1]:

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Loose Bulk Density - (sometimes called the poured bulk density) of a bulk material is the weight per unit of volume that has been measured when the sample is in a loose, non-compacted or poured condition.

Packed Bulk Density - of a bulk material is the weight per unit volume that has been measured when the sample has been packed or compacted in, for instance, a silo or bin or after containerized transportation.

Since the material is compacted the entrained air is displaced and the void space is reduced. As a result, the value of packed bulk density is higher than that of loose bulk density.

Fluidized Bulk Density - is the apparent bulk density of a material in its fluidized state. It is generally lower than either the packed or loose bulk density due to the air absorbed into the voids.

Bulk density is a property that defines the bulk material as a whole. The density of the individual particle is referred to as the particle density.

Particle Density - is the mass of a particle divided by its volume. For a bulk material, average particle density is used, found by dividing the mass of the material by its volume, excluding the voids.

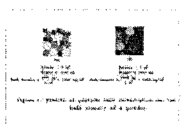
The unit of bulk density and particle density is kg/m^3 or lb/ft^3.

Particle Size Distribution & Bulk Density

The particle size distribution of powders and particle shape has an effect on the packing characteristics, and therefore their bulk density. The smaller particles of a size distribution occupy the interstices between the larger particles creating a densely packed powder with higher bulk density. This is illustrated in figure 1. Densely packed powders usually have flowability difficulties. This is one reason why bulk materials with high bulk density require greater power for blending than materials with lower bulk density.

In addition, large coarse particles with higher molecular weight tend to the settle at the bottom of the blender vessel; whereas the finer particles float at the top of the top blender in the form of fine dust. Therefore, process engineers should be careful while selecting blenders for ingredients with large differences in bulk densities and particle size distribution.

Particle Size Distribution & Bulk Density



Blender Volume & Bulk Density

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Specifying blender capacities in weight per batch (kg / batch) or weight per hour (kg/hr) is a common mistake made by process engineers while preparing the technical data sheet for blenders. Blenders are designed and manufactured primarily on the basis of the volumetric capacity of material that they can handle.

The total volumetric capacity is equal to the volume of the mixing vessel. The working volumetric capacity of the blender is maximum recommended volume up to which the material should be filled inside the blender to ensure homogenous and efficient blending. The recommended working volumetric capacity of blenders is generally 30% to 70% of the total volumetric capacity. The percentage fill up may vary depending on the type of blender.

For example, the recommended fill-up volume for the double cone blender is 50% to 60% of the total blender volume. The approximate blend time in a production size double cone blender with different fill up volumes is as shown below. Trials have proved that homogenous blending is not achievable with 80% fill up volume in a double cone blender.

Effect of blender fill up volume on blending time of double cone blender: % fill up of blender and volume approximate blend time in minutes

- 50% 10 min.
- 65% 14 min.
- 70% 18 min.
- 75% 24 min.
- 80% 40 min.

The gravimetric or weight capacity of a batch blender is the weight of material that can be processed per batch. The maximum weight of the material that can be blended depends on the average bulk density of the ingredients. It is limited by the connected power to the blender.

The total weight of material that can be charged into a blender is the product of the working volume and the bulk density of the material. If loose bulk density is considered, the batch weight shall be lower. However, if calculation is using the packed bulk density, the batch weight shall be higher. The packed bulk density and the fluidized bulk density do not compare to the conditions that are most likely to occur in a blender. Therefore, for the purpose of blender design, the loose bulk density of the material should be considered.

For practical selection, it is recommended that a simple experiment be carried out for determining the bulk density to be used for calculation. Charge a pre-weighed quantity of material into a calibrated measuring cylinder placed still on table. Do not tap the cylinder while pouring the material. Divide the weight of the material poured by the corresponding volume occupied for calculating the bulk density. This bulk density can be utilized as a reliable measure for calculation of batch capacity of the blender.

Most applications involve blending of more than one ingredient. In such cases the average bulk density of the ingredients should be considered for calculation. For example, if a blend comprises of 25% of ingredient A, having bulk density of 500 kg/m3 and 75% of ingredient B, having bulk density of 1000 kg/m3 , the average bulk density should be calculated as follows:

Average Bulk Density = (0.25 x 500) + (0.75 x 1000) = 875 kg/m^3

Power Consumption & Bulk Density

The power required for blending depends on the weight of material in the blender. Light materials that have a lower bulk density shall require less power for blending compared to heavier materials. Thus, the connected motor of a blender for the same volumetric capacity shall be higher for heavy solids as compared to light solids. This is illustrated below:

Case 1:

Total volume – 1.4 m^3

Working volume = 0.7 x Total volume = 0.98 m3 (say 1 m^3)

Bulk density of material to be blended – 1000 kg/m^3

Batch weight = Working Volume x Bulk Density = 1000 kg

Recommended connected power for 1 m^3 blender, for 1000 kg batch = 15 HP

Case 2:

Total volume – 1.4 m^3

Working volume = 0.7 x Total volume = 0.98 m^3 (say 1 m^3)

Bulk density of material to be blended – 500 kg/m^3

Batch weight = Working Volume x Bulk Density = 500 kg

Recommended connected power for 1 m^3 blender, for 500 kg batch = 10 HP

It may be noted that the actual power required for blending would be lower than the ratings stated above. The connected motor HP is selected after accounting the transmission losses of the drive system.

The bulk density of ingredients to be blended is an important material property to be considered while designing blenders. The weight of material that can be blended per batch and the power required for blending largely depend on the bulk density.

References

1. CEMA Standard No. 805, "Glossary of Pneumatic Conveying Terms - 2005"
2. Sweitzer, G.R., Blending and Drying Efficiency Double Cone vs. V-Shape, Gemco, Newark, New Jersey
3. Tekchandaney R. Jayesh, "Material Properties Affecting Solids Blending & Blender Selection: Flowability"

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Sevak Umesh — May 16, 2010 4:44 AM

Horse Power calculation for double cone blender

Refer to case 1 & case 2 of Double Cone Blender's motor HP rating, Can you explain me how the figure 15HP & 10Hp comes? What is the exact formula for calculating motor horse power for double cone powder blender?

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Density - Definition

For other meanings of density, see density (disambiguation)

Density (symbol: ρ - Greek: rho) is a measure of mass per unit of volume. The higher an object's density, the higher its mass per volume. The *average density* of an object equals its total mass divided by its total volume. A denser object (such as iron) will have less volume than an equal mass of some less dense substance (such as water).

The **SI unit** of density is the kilogram per cubic metre (**kg/m^3**)

<math>\rho = \frac{m}{V}<math>

where

ρ is the object's density (measured in kilograms per cubic metre)

m is the object's total mass (measured in kilograms)

V is the object's total volume (measured in cubic metres)

Contents

Various types of density

Under specified conditions of temperature and pressure, density of a fluid is defined as described above. However, the density of a solid material can be different, depending on exactly how it is defined. Take sand for example. If you gently fill a container with sand, and divide the mass of sand by the container volume you get a value termed *loose bulk density*. If you took this same container and tapped on it repeatedly, allowing the sand to settle and pack together, and then calculate the results, you get a value termed *tapped* or *packed bulk density*. Tapped bulk density is always greater than or equal to loose bulk density. In both types of bulk density, some of the volume is taken up by the spaces between the grains of sand. If you are interested in the density of the grain of sand itself you need to measure either *envelope density* or *absolute density*.

Other units

Density in terms of the SI base units is expressed in terms of [kilogram]]s per cubic metre (kg/m^3). Other units fully within the SI include grams per cubic centimetre (g/cm^3) and megagrams per cubic metre (Mg/m^3). Since both the litre and the tonne or metric ton are also acceptable for use with the SI, a wide variety of units such as kilograms per litre (kg/L) are also used.

1000 kg/m^3= 1 t/m^3 = 1 kg/dm^3 = 1 kg/L = 1 g/cm^3 = 1 g/mL

In Imperial units or U.S. customary units, the units of density include pounds per cubic foot (lb/ft^3), pounds per cubic yard (lb/yd^3), pounds per cubic inch (lb/in^3), ounces per cubic inch (oz/in^3), pounds per gallon (for U.S. or imperial gallons) (lb/gal), pounds per U.S. bushel (lb/bu), in some engineering calculations slugs per cubic foot, and other less common units.

The maximum density of pure water at a pressure of one standard atmosphere is 999.972 kg/m^3 at a temperature of about 3.98 °C (277.13 K).

From 1901 to 1964, a litre was defined as exactly the volume of 1 kg of water at maximum density, and the maximum density of pure water was 1.000 000 kg/L (now 0.999 972 kg/L). However, while that definition of the litre was in effect, just as it is now, the maximum density of pure water was 0.999 972 kg/dm^3. During that period students had to learn the esoteric fact that a cubic centimetre and a millilitre were slightly different volumes, with 1 mL = 1.000 028 cm^3. (often stated as 1.000 027 cm^3 in earlier literature).

Measurement of density

A common device for measuring fluid density is a pycnometer. A device for measuring absolute density of a solid is a gas pycnometer.

Density of substances

Perhaps the highest density known is reached in neutron star matter (see neutronium). The singularity at the centre of a black hole, according to general relativity, does not have any volume, so its density is undefined.

The densest naturally occurring substance on Earth is Iridium, at about is 22,650 kg/m^3.

A table of densities of various substances:

Substance	Density in kg/m^3
Iridium	22,650
Osmium	22,610
Platinum	21,450
Gold	19,300
Uranium	19,050
Mercury	13,580
Palladium	12,023
Lead	11,340
Silver	10,490
Copper	8,920
Iron	7,870
Tin	7,310
Titanium	4,507
Diamond	3,500
Aluminium	2,700
Magnesium	1,740
Seawater	1,025
Water	**1,000**
Ethyl alcohol	790
Gasoline	730
Aerogel	3

any gas	0.0446 times the average molecular mass, hence between 0.09 and ca. 10 (at standard temperature and pressure)
For example air	1.2

See also density of gas

Note the low density of aluminium compared to most other metals. For this reason, aircraft are made of aluminium. Also note that air has a nonzero, albeit small, density. Aerogel is the world's lightest solid. **Table - density of air ρ, Speed of sound in air c,**
acoustic impedance Z vs. temperature °C

Impact of temperature			
°C	c in m/s	ρ in kg/m³	Z in N·s/m³
- 10	325.4	1.341	436.5
- 5	328.5	1.316	432.4
0	331.5	1.293	428.3
+ 5	334.5	1.269	424.5
+ 10	337.5	1.247	420.7
+ 15	340.5	1.225	417.0
+ 20	343.4	1.204	413.5
+ 25	346.3	1.184	410.0
+ 30	349.2	1.164	406.6

Relative density

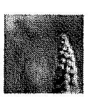
Relative density, formerly called **specific gravity**, is a dimensionless quantity defined as the density of a substance divided by the density of water at standard temperature and pressure. By definition, then, the relative density (or RD) of water is 1, and the RD of osmium is about 22.

See also

- ISO 31: **volumic mass**
- Dord
- Standard temperature and pressure
- Relative density

Density - Example Usage

UncleMatts: A new study from Washington State proves organic strawberries are superior in nutrient **Density**, flavor, and soil health. http://ow.ly/2z1qx



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